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QUENCH HARDENING AND MECHANICAL CHARACTERIZATION OF AISI 4140 STEEL

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ABSTRACT

AISI 4140 steel is the medium carbon low chromium steel used for a variety of structural applications. Generally this type of steel is available commercially in hot/cold rolled or as-cast conditions. This grade of steel has moderate strength and suitably responds almost to all type of heat treatments especially, hardening treatments. The present work is the effort in improving the mechanical properties of AISI 4140 steel by hardening treatment using different quenchants such as tap water, salt water (brine solution), ice water, castor oil, and coconut oil. Properties under consideration are wear, hardness and tensile strength. The change in property obtained by quenching is compared with that of as-bought steel. Ice water, coconut oil and castor oil quenched specimens show good wear resistance properties. Specimens quenched in ice water shows high hardness value (Rc 51.25). Castor oil quenched specimens show a highest percentage displacement (27.33%) and ultimate tensile strength of 1600.3N/mm2. Amongst the different quenchants used castor oil shows good result as a whole.

***KEYWORDS:** Quenchant, Hardening, AISI 4140 Steel, Ice Water, Tensile Strength & Wear*

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Original Article

INTRODUCTION

The liability for mechanical testing of materials may be a critical aspect of engineering practice. Today, all the more consideration is, no doubt provided for the interpretation of test results in terms of service performance, as well as giving reliable indications of the ability of the material to perform certain types of duty. Mechanical tests would additionally be utilized in investigational work to obtain information for use in design to ascertain whether the material meets the specifications for its intended use. For this purpose, the tests should provide the information accurately, rapidly and economically [1, 2].

An extensive variety of mechanical segments are generated through forming processes, which are later followed by heat treatment processes. Heat treatment is a methodology of blending separate operations including heating and cooling of metal which should change its mechanical properties. Heat treatment is used to improve the properties of steel. The obliged property might be improved with or without the phase changes in room temperature [3]. Steel may be characterized as an alloy of iron and carbon with the carbon content between a few hundredths of a percent up to about 2% by wt. Other alloying components can add upto 5% by wt. in low alloy steels and higher (upto 60% by wt.) in high alloyed steels. Heat treatment may be regularly employed to change the mechanical properties of an alloy, manipulating properties, for example, such as hardness, toughness, ductility and elasticity [4]. Quenching treatment after performing after mechanical forming operation, strengthens the component with high hardness to improve the sturdiness. It may be basically relevant on steels where the point is to change the

delicate high temperature austenitic structure to hard martensite [5].

Austenization or solution treating temperature might range from 780°C for plain carbon steels to as high as 1250°C for high alloy tool steels [6]. To accomplish martensite structure, the cooling needs to be quick enough to forestall the creation of other stages like pearlite and bainite. Martensite is supersaturated solid solution with the body centered tetragonal form like square prism shape macroscopically [5, 7, 8]. Quenching being one of the most important process of heat treatment, can be used to improve the performance of metallic alloys greatly, but an important side effect being the formation of thermal and transformational residual stresses that cause changes in size and shape which results in distortion and hence generates cracks. However, this methodology usually makes undesired geometric distortions in the quenched parts [9]. Hence the challenge behind the quenching is to choose the proper quenching medium which will cause minimum stress generation thereby reduce distortion as well as cracking [10]. Medium carbon steel with a higher range of carbon (0.509 wt%) shows excellent hardness value for water and SAE 40 engine oil quenching. Toughness of this steel is improved by quenching in palm kernel oil, cotton seed oil and olive oil [8]. Biodegradable quenchants improve the mechanical properties of medium carbon steel compared to petroleum oil quenchants [11]. Heat conducting properties of vegetable oils are better than the petroleum oil based quenchants [12].

EXPERIMENTAL PROCEDURE

Chemical Composition

Table 1 shows the chemical composition of AISI 4140 steel used for the present work.

Table 1: Chemical Composition of AISI 4140 Steel

Element	C	Si	Mn	P	S	Cr	Mo	Fe
Actual (Wt. %)	0.3810	0.1900	0.7020	0.0280	0.0040	1.0400	0.2500	Balance
Allowable (Wt. %)	0.3600-0.4400	0.1000-0.4000	0.7000-1.0000	0.0350 (Max.)	0.0400 (Max.)	0.9000-1.2000	0.2500-0.3500	Balance

Specimen Preparation

Standard specimens are prepared with the required dimensions for wear, hardness and tensile tests. ASTM G-99, ASTM E18-02 and ASTM E8M cylindrical specimens are prepared for wear, hardness and tensile tests respectively by turning and polishing.

Heat Treatment Procedure

Specimens are heated to the austenitic state (900°C) in an electric furnace. Furnace temperature is maintained at 900°C for one and half hour to convert the room temperature structure into austenite followed by quenching in different media like water, coconut oil, castor oil, salt water, ice water (Ice cubes with salt) for 15 minutes. Later all the specimens are cleaned by emery paper. The specimens are then stored in an air-tight containers.

Testing

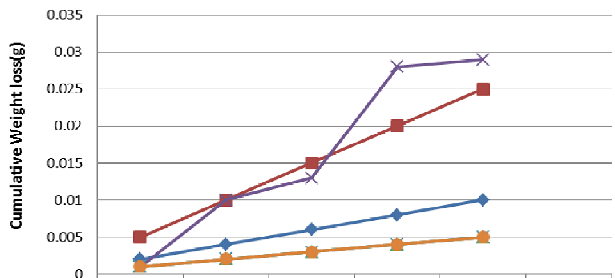
The heat treated specimens are further subjected to mechanical tests like wear (Pin-on-disc, Ducom Instruments), hardness (Rockwell) and tensile test (Tensometer). Wear test is performed with parameters are: Diameter of the wear track 120mm, test duration 30minutes and speed of the disc 400 rpm for each specimen. Hardness test is performed on Rockwell hardness tester with diamond cone indenter, load range 150 kgf. Tensile test is performed on Electronic Tensometer

(Kudale instruments Model-PC 2000) with cross head speed of 2mm per minute.

RESULTS AND DISCUSSIONS

Wear Test

The wear test result shows that castor oil/coconut oil/ice water quenched specimens have same wear rate and excellent wear resistance compared to other specimens [Figure 1]. Salt water quenched specimen shows poor wear resistance. The salt water quenched specimen's wear at lower distances of the run is mild but as the sliding distance increases wear pattern is erratic and severe. With the long duration run, due to strain hardening, the interface becomes more brittle and the residual stresses may give room for crack formation and chipping of the interface regions as larger debris by poor impact resistance. Moreover salt present in the quenchant periodically explodes the vapour blanket formed during secondary stage of quenching process so that heat removal is very fast, generates huge residual stresses in the specimen [13]. All other quenched specimens (except salt water quench) shows linear wear rate with respect to sliding distance. The quenched specimen converts the room temperature phase as martensite, the difference in the properties associated is the level of residual stresses present [5]. Water quenching gives martensite structure with lot of residual stresses. This makes the specimen highly brittle in nature. During wear test, the impact load acting on the specimen may remove the material in the form of larger debris due to lack in toughness. This increases the wear rate.



Sliding Distance (Km)	4.523	9.047	13.571	18.095	22.169
As bought	0.002	0.004	0.006	0.008	0.01
Water quenched	0.005	0.01	0.015	0.02	0.025
Ice water quenched	0.001	0.002	0.003	0.004	0.005
Salt water quenched	0.001	0.01	0.013	0.028	0.029
Coconut oil quenched	0.001	0.002	0.003	0.004	0.005
Castor oil quenched	0.001	0.002	0.003	0.004	0.005

Figure 1: Wear Rate Comparison of as Bought as Well as Quenched Specimens of AISI 4140 Steel

Hardness Test

Ice water quenched specimen shows excellent hardness followed by salt water quenched [Figure 2]. Surprisingly castor oil shows better hardness than water quenched and coconut oil quenched. Coconut oil and water quenching show almost the same result. The hardness improvement is associated with the type, nature and the amount of martensite formation [13]. Ice water quenched shows excellent hardness due to more weight percentage of martensite formation. The weight percentage of martensite formed depends upon the transformation temperature. Lower the temperature, the larger is the amount of martensite formation and higher is the hardness. As-bought specimen shows lower hardness value due to no martensite presence in its room temperature structure.

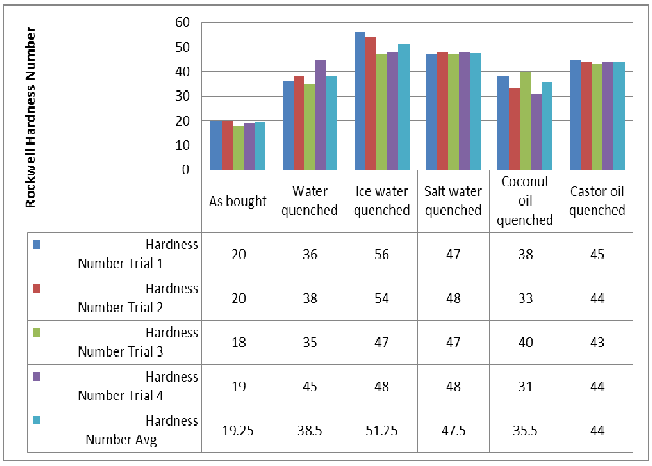


Figure 2: Rockwell Hardness Number Comparison of as Bought as Well as Quenched Specimens of AISI 4140 Steel

Tensile Test

From the load versus displacement graphs [Figure 3] engineering UTS, break strength, percentage displacement at peak and break are noted. The nature of load versus displacement graphs remains almost same with changing UTS and other properties. The UTS is excellent for castor oil quench followed by ice water, salt water and coconut oil quenched. Water quenched is the lower and as bought is lowest. A similar trend is observed in break strength values also. There is almost additional 100% increase in the UTS values compared to as bought. The strength variation trend is well supported by hardness variation trend. The hardness and strength go hand in hand. This accomplishment in better strength may be attributed to the ability of martensite formation on quenching [5].

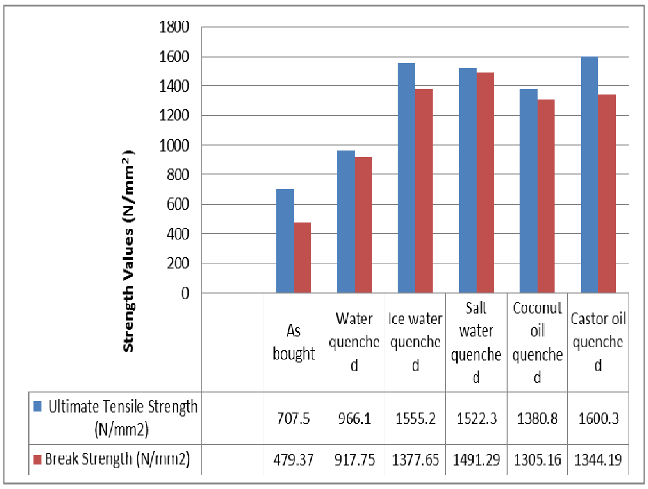


Figure 3: Ultimate Tensile Strength (UTS) and Break Strength Comparison of as Bought and Quenched Specimens of AISI 4140 Steel

Ductility variation is minor in all the specimens. Water quenched and as bought specimens show lower ductility (at peak) compared to other quenching medium [Figure 4]. Castor oil quenched shows excellent ductility compared to other quenchants. Higher ductility in quenched specimens may be attributed to the inability of the specimen to form a fully martensite structure. Ferrite and pearlite free martensite always shows poor ductility [13].

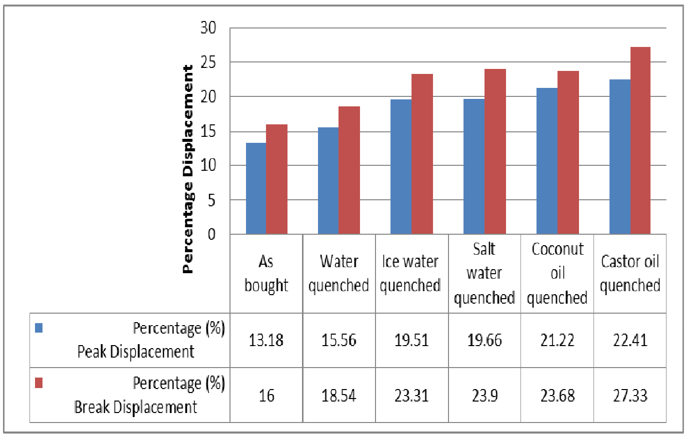


Figure 4: Ductility Comparison of as Bought and Quenched Specimens of AISI 4140 Steel

CONCLUSIONS

The specimens are heat treated and the results are as per the expectation. The quenchants behave suitably for property alterations. The following conclusions are arrived from the experimental work.

- Castor oil/coconut oil/ice water quenched specimens have same wear rate and excellent wear resistance. Salt water quenched specimen shows poor wear resistance which is almost 6 times poor than the best performers in the long run (2.5 hours run).
- Ice water quenched specimen shows excellent hardness followed by salt water quenched and records nearly 17% improvement compared to castor oil quenched one.
- The UTS is excellent for castor oil quench followed by ice water, salt water and coconut oil quenched. Water quenched is the lower and as bought is lowest. Castor oil quenched records nearly 17% improvement in UTS compared to water quenched one. No markable change is observed in break strength values.
- Water quenched and as bought specimens show lower ductility (at peak) compared to other quenching medium. Castor oil quenched shows excellent ductility compared to other quenchants.

REFERENCES

1. *Ahaneku I. E., A. R. Kamal, O. A. Ogunjirin. Effects of Heat Treatment on the Properties of Mild Steel Using Different Quenchants. Frontiers in Science, DOI: 10.5923/j.fs.20120206.04, 2012;2(6):153-158.*
2. *W. F. Smith. Principles of Materials Science and Engineering, McGraw-Hill, 1990.*
3. *Gorni A A. Steel Forming and Heat Treating Handbook, Sao Vacente, Brazil; 2006.*
4. *Gurumurthy, S. S. Sharma, Gowrishankar, Sowmith, Abhishek and Abhishek Devar. Study of Mechanical Properties of Dual Phase EN19 Steel (AISI4140). Indian Journal of Science and Technology,, DOI: 10.17485/ijst/2016/v9i37/97422, 2016;9(37):1-6.*
5. *Sumi, N., & Malathy, R. (2013). Experimental investigation on effect of fly ash and steel slag in concrete pavements. International Journal of Research in Engineering & Technology (IJRET), 1(2), 117-124.*
6. *Alabi Abdulmumin A, Obi Anthony I, Yawas Danjuma S., Samotu Ibraheem A, Stephen Sam I. M. Effect of Water Temperature on the Mechanical Properties of Water Quenched Medium Carbon Steel. Journal of Energy Technologies and Policy*

www.iiste.org ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online); 2012;2(4):40-45.

7. *Dhiraj Nhika Chaudari, Raghunath Yadav Patil & Atul Shivaji Chaudhari. Effect of Quenching Parameters on Material Characteristics of Specimen- an Overview. International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) ISSN(P): 2249-6890; ISSN(E): 224209-8001; 2015;5(4):25-32.*
8. *Ali RafaAltaweel, Majid Tolouei-Rad. Effect of Quenching Media, Specimen Size and Shape on the Hardenability of AISI 4140 Steel. Emirates Journal for Engineering Research, 2014;19(2):33-39.*
9. *Yadav, D., & Gaikwad, A. (2015). Comparison and testing of tensile strength for low & medium carbon steel. International Journal of Mechanical Engineering (IJME), 4(5), 1-8.*
10. *M. Dauda, L. S. Kuburi, D. O. Obada, and R. I. Mustapha. Effect of Various Quenching Media on Mechanical Properties of Annealed 0.509 wt% C-0.178 wt% Mn Steel. Nigerian Journal of Technology (NIJOTECH), Vol. 34 No.3, ISSN: 0331-8443. pp. 506-512; July 2015.*
11. *Totten, G. E., Howes, Maurice A. H. Steel Heat Treatment Handbook. Marcel Dekker, Inc., 1997.*
12. *Chaves, J. C. The Effect of Surface Condition and High Temperature Oxidation on Quenching Performance of 4140 Steesl in Mineral Oil. Int. Manufacturing Engineering. Worcester Polytechnic Institute: Worcester, 2001.*
13. *KM, A. F., & VARGHESE, S. (2014). Behavioural study of steel fiber and polypropylene fiber reinforced concrete. Int. J. Res. Eng. Technol., 2(10).*
14. *Rajkumar Shinde, Dinesh Rao. Influence of Petroleum and Biodegradable Quenchants on Properties of medium carbon Steels. ISSN: 2278 – 7798, International Journal of Science, Engineering and Technology Research (IJSETR), 2013;2(11):2052-2056.*
15. *Nikolai Ivanovich Kobasko – Ester Carvalho de Souza, Lauralice de compos Franceshini Canale – George Edward Totten. Vegetable oil Quenchants: Calculation and Comparison of the Cooling Properties of a Series of vegetable Oils. Strojniski vestnik – Journal of Mechanical Engineering, 2010;56:131-142.*
16. *Avner S. H. Introduction to Physical Metallurgy. Second edition, Tata McGraw Hill, 1976.*